TERRACORE

Proposed Geotechnical Investigations at a Site at Oratorju Qalb Ta' Gesu, Mosta.

Site Investigations at Pjazza Dun Angelo Camilleri, Mosta.

Ground Investigations Report

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FOREWARD

Recommendations presented in this report are based on the findings from the locations where the boreholes were drilled and for which the laboratory test results were carried out. Therefore, the Report may not represent all conditions that the Client/Architect/Engineer may encounter later on during the course of site works (including excavation, clearing of site etc.) on the said project. Whilst opinions may be expressed relating to sub-soil conditions in parts of the site not investigated, for example away from the location of the boreholes drilled, these are only for guidance and no liability can be accepted for their accuracy.

It is imperative that the following report is read in its entirety. The geological and geotechnical findings provided in this document should not be relied upon for any specific application without thorough and competent examination and verification of its accuracy, suitability and applicability by qualified professionals.

The rocks and soils encountered and the samples retained represent a limited amount of the material present in the subsurface at the site. Although the investigation recovered representative samples of the geological materials present, some material present on the site may not have been examined. Should significantly different rocks or soils be determined during site works, then further investigation may prove necessary.

Unless otherwise stated in this report, drilling us undertaken using rotatory techniques. This method is regarded as being one of the most reliable.

Boring and sampling procedures are undertaken in accordance with:

- BS 5930:1999 – Code of practice for ground investigations.
- EN 1997:2:2007- Geotechnical Design Part 2: Ground Investigation and testing.

1. INTRODUCTION

TERRACORE Ltd. was commissioned by Mosta Parish Church to undertake a site investigation at Pjazza Dun Angelo Camilleri, Mosta. (**Figure 1**).

Figure 1: Ariel Photo indicating site location at Pjazza Dun Angelo Camilleri, Mosta. *(Source: Google Earth)*

2. SCOPE OF WORK – DESIGN METHODOLOGY

The aim of the investigation is to identify the existing terrain conditions, top of bedrock and the presence of clay beds, caverns and voids as well as the quality of clay-soil beneath.

For the fulfilment of the Evaluation and subsequent Interpretation Scope, the design methodology was dictated by the following successive stages:

- *Desk study and evaluation* of the available geological, geotechnical and hydrogeological information. Moreover, problematic or instable locations are taken also into account. These included among others, the formations involved in the project area, the indicated major or minor hazards such as faults, disturbance zones, major or minor instabilities, the orientation of the main structural features of the formations in relation to the project layout, the prevailing groundwater regime etc.
- *Observation on site of the main elements of the geotechnical investigations.* At this stage, the site was visited by experienced engineering geologists of the design team and the main elements of the geology were recorded and verified, in conjunction of the examination of the borehole cores.
- *Detailed evaluation of the existing information* through the conclusions obtained in the course of on-site verification. The particular design stage included the evaluation of the statistical processing of the laboratory test results and the arrangement of the geotechnical units.
- *Combination of the collected, verified and evaluated information* and development of the pertinent general geological and geotechnical model for the project area.

Sampling and testing should comply with the relevant standards (unless otherwise agreed, BS standards or other recognised equivalents should be used), and should extend to a sufficient depth below the deepest level of the proposed development (taking into consideration all proposed excavations and underground structures). Wherever the study involves the drilling of core samples, the number, depth and location thereof should also be submitted for EPD approval prior to carrying out of any in situ tests.

3. STANDARDS & GUIDANCE

The site investigation was conducted in full accordance with *BS 5930:2015 "Code of practice for geological site investigations"*, *BS EN 1997:2004 "Geotechnical Design – Part 1: General Rules"* and *BS EN 1997-2:2007 "Geotechnical Design - Part 2: Ground Investigation and Testing"*.

Uniaxial compressive strength tests on rock samples were performed according to the *International Society for Rock Mechanics (ISRM) suggested methods and Annex W of EN 1997-2:2007.*

4. AVAILABLE DATA

For the implementation of the present final report, the following documents were taken into consideration:

[1] Google Earth Images.

[2] Ground Floor Level Showing Borehole Locations. (Source: Drawing no. SL(2-)1000)

5. SITE LOCATION & PROJECT DESCRIPTION

5.1 Site Location

The investigated site is located at Pjazza Dun Angelo Camilleri, Mosta and is indicated in **Figure 1**. Along with this the Ground Floor Level Showing Borehole Location has been provided in **Figure 2 below.**

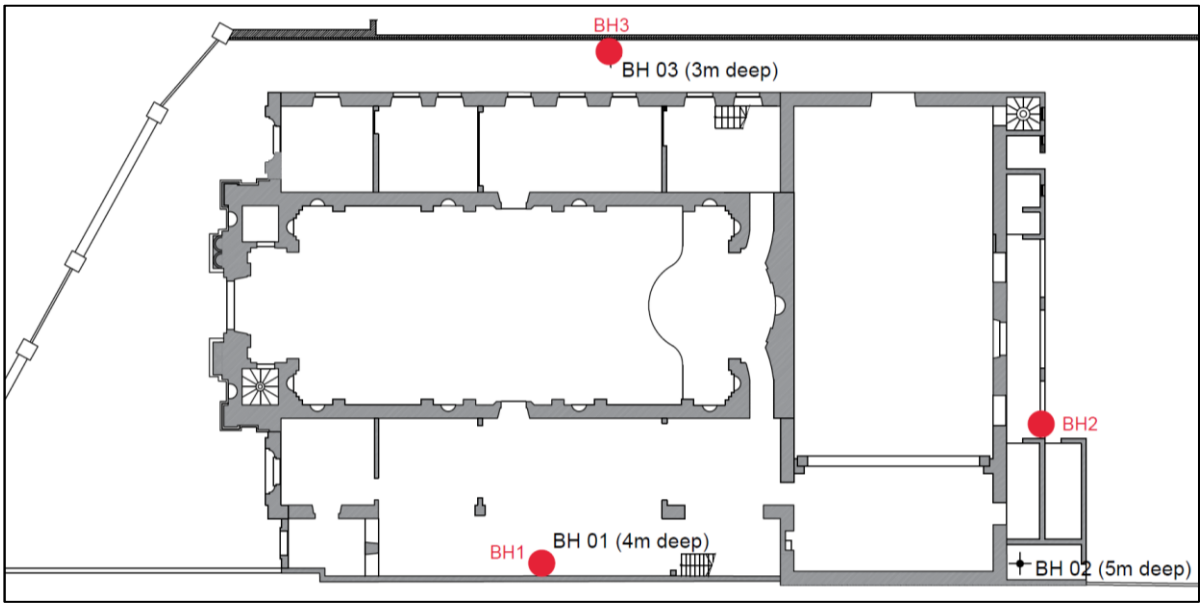

Figure 2: Ground Floor Level Showing Borehole Locations. *(Source: Drawing no. SL (2-)1000)*

5.2 Project Description

The site location has been provided in Figure 1. It lies at an altitude of about 71 m above sea level. Its North boundary is marked by Barrieri c/w Stivala whereas its South, West and East boundaries are marked by Third Party Properties. (See **Figure 1**)

6. GEOLOGY OF THE AREA

6.1 Geological Setting of Malta

The Maltese strata comprise hard, massive sometimes reefal, tectonically competent coralline limestones, ductile fine grained biomicrites and plastic marls and clays of a tectonically incompetent behaviour. The litho and Chrono stratigraphical rock succession and the paleo-environment of the Maltese Islands have been studied in detail by Murray (1890), Felix (1973), Pedley (1978), Pedley *et al.* (1978), Di Geronimo *et al.* (1981). According to these authors they consist of the following formations (from youngest to oldest):

1. **Upper Coralline Limestone Formation:** up to 162m thick, represented by shallow water facies ranging from subtidal through intertidal and supratidal environments.
2. **Greensand Formation:** up to 12m glauconitic limestones.
3. **Blue clay Formation:** up to 65m slightly consolidated marls which have been deposited in an open marine environment at sea-depth between 200 and 40 m.
4. **Globigerina Limestone Formation:** a 23 - 207m thick sequence of fine-grained biomicrites with intercalated layers of phosphorite nodules. These series have been deposited at water depth between 40 and 150m in a shallow shelf area.
5. **Lower Coralline Limestone Formation:** exposed above sea level up to 140m, represented by a shallow water facies formed at sea-depth of less than 50 m.

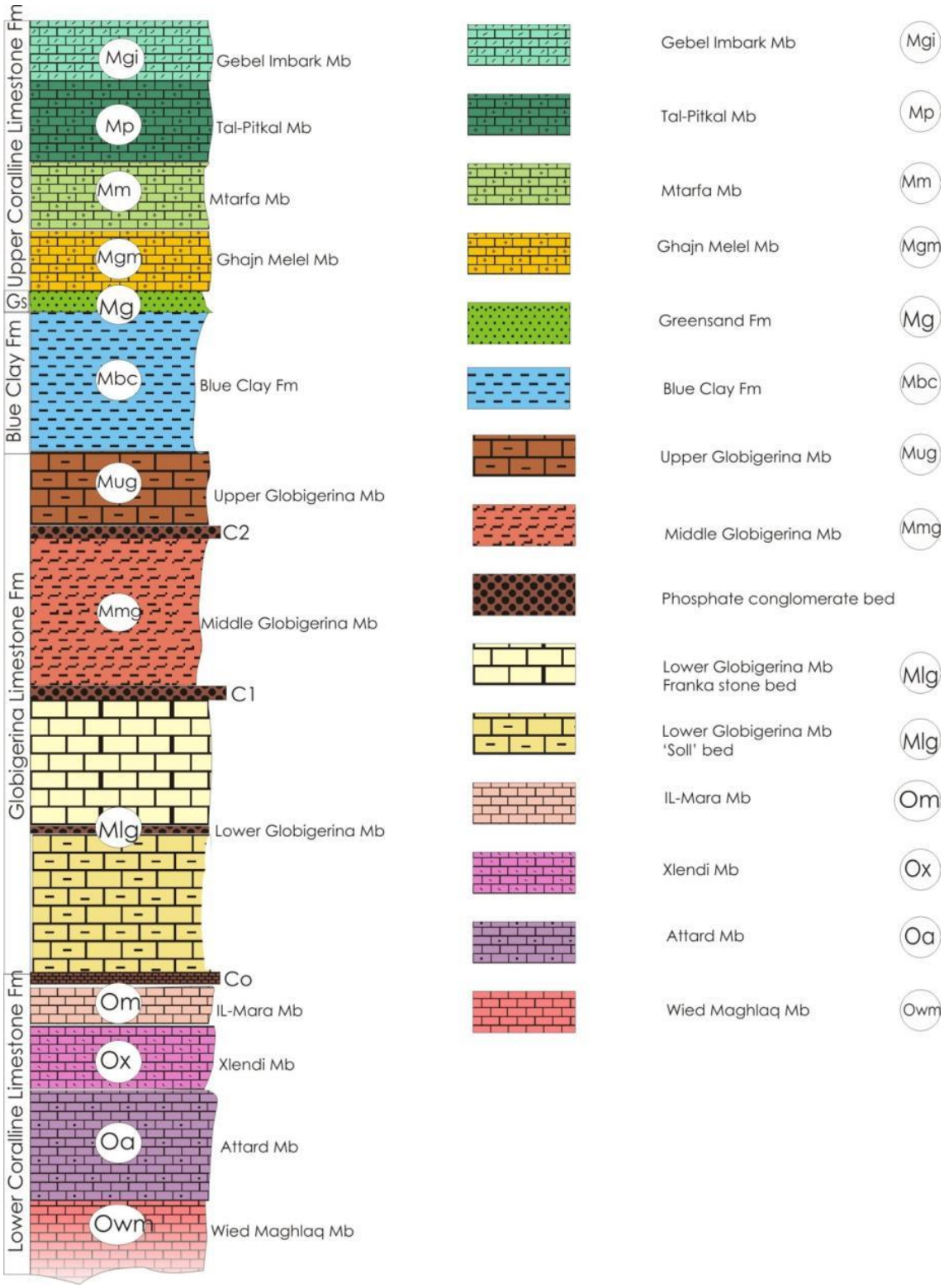

Figure 3: Litho-stratigraphy of the Maltese Islands.

6.2 Geological Conditions along the project area

The extract from the published geological Map of the Maltese islands (1993) shown in **Figure 4** below indicates that the site (marked in red) is located on the Lower Coralline Limestone Formation.

The the Mara Member (Om) of the Lower Coralline Limestone are tabular beds of pale-cream to pale-grey crabonate mudstones, wackestones and packstones in 1 to 2 km think units.

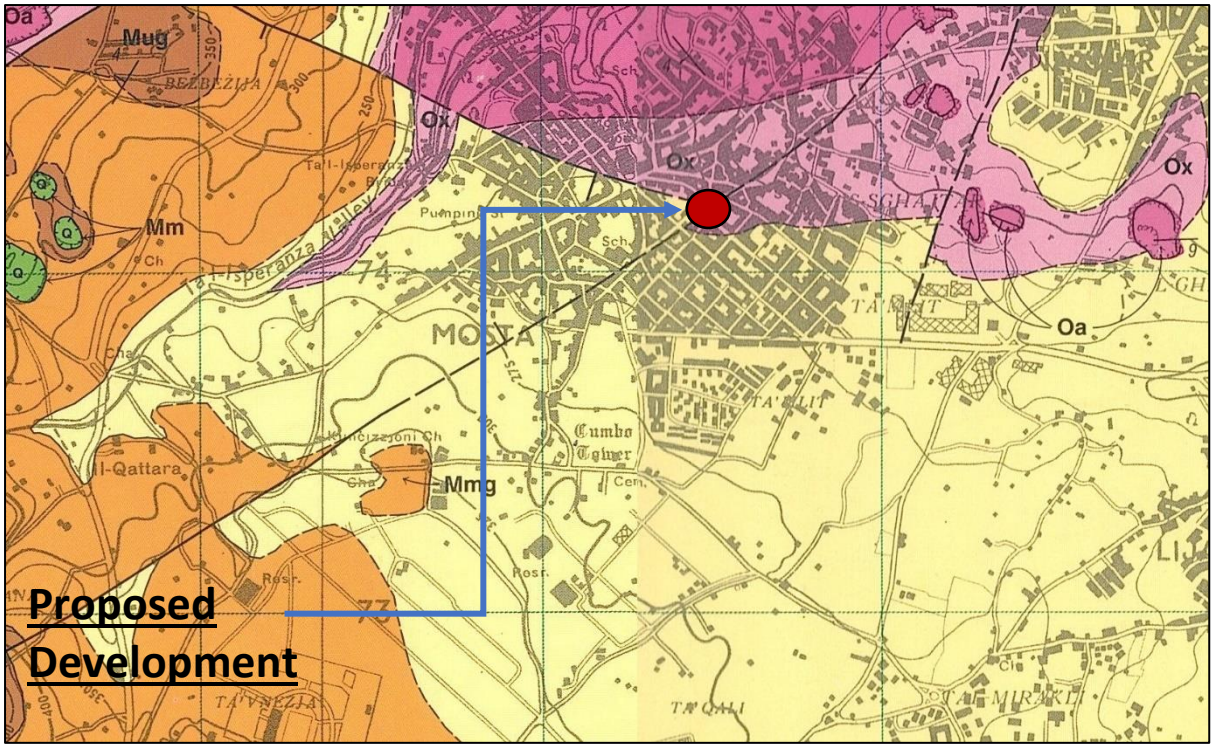

Figure 4: Geological map extract showing the geology of the area and the geological description of the rock formation (Source: Geological Map of the Maltese Islands, 1993)

7. GEOTECHNICAL INVESTIGATIONS & PREDICTIONS

7.1 Site Works - In situ investigations

Fieldwork was undertaken on the 28th of September 2022, and comprised the drilling and testing of three (3) boreholes, denoted as BH-1 to BH-3. The approximate position of these boreholes is indicated in the Ground Floor Plan in **Figure 2.**

The borehole drilling records are shown in **Appendix 2** and summarized in **Table 1** below.

	BH-1	***BH-2***	***BH-3***
Date drilled	28/09/2022	28/09/2022	28/09/2022
Existing Foundation Level *(m)*	2.00	1.02	0.73
Top of bedrock *(m)*	2.00	1.02	0.73
Coring run *(m)*	0.00 – 4.00	0.00 – 4.00	0.00 – 3.00
Total depth *(m)*	4.00	4.00	3.00

Table 1: Borehole drilling records. (BH-1 to BH-3)

7.2 Classification

The main geological stratum encountered during the investigation is:

- White to cream, Weak, Lower Coralline Limestone of “Poor” to “Excellent” quality.

Photographs of the rock core recovered are shown in **Appendix 3**. The borehole logs are located in **Appendix 5**.

7.3 Groundwater conditions

No data for the measured water level after drilling has been encountered in the boreholes.

7.4 Rock Quality

Table 2 below shows the values of the quality of the rock cores recovered namely the Total Core Recovery (TCR), the Solid Core Recovery (SCR), the Rock Quality Designation (RQD) and the Fracture Index. These parameters are described in **Figure 6** as per BS5930:2015.

BH No.	Run No.	Depth *(m)*	TCR *(%)*	SCR *(%)*	RQD *(%)*	Rock Quality	Fracture Index *(fractures/m)*
BH-1	1	2.00-3.00	100	92	60	Fair	Moderately Fractured
	2	3.00-4.00	35	35	35	Poor	0/m
BH-2	1	1.02-2.00	100	100	90	Excellent	1/0.98m
		2.00-3.00	100	100	100	Excellent	0/m
	2	3.00-4.00	40	40	40	Poor	0/m
BH-3	1	0.73-2.00	100	98	91	Excellent	0/0.27m
		2.00-3.00	100	98	95	Excellent	0/m

Table 2: Quality of rock core: TCR, SCR, RQD and Fracture Index. (BH-1 to BH-3)

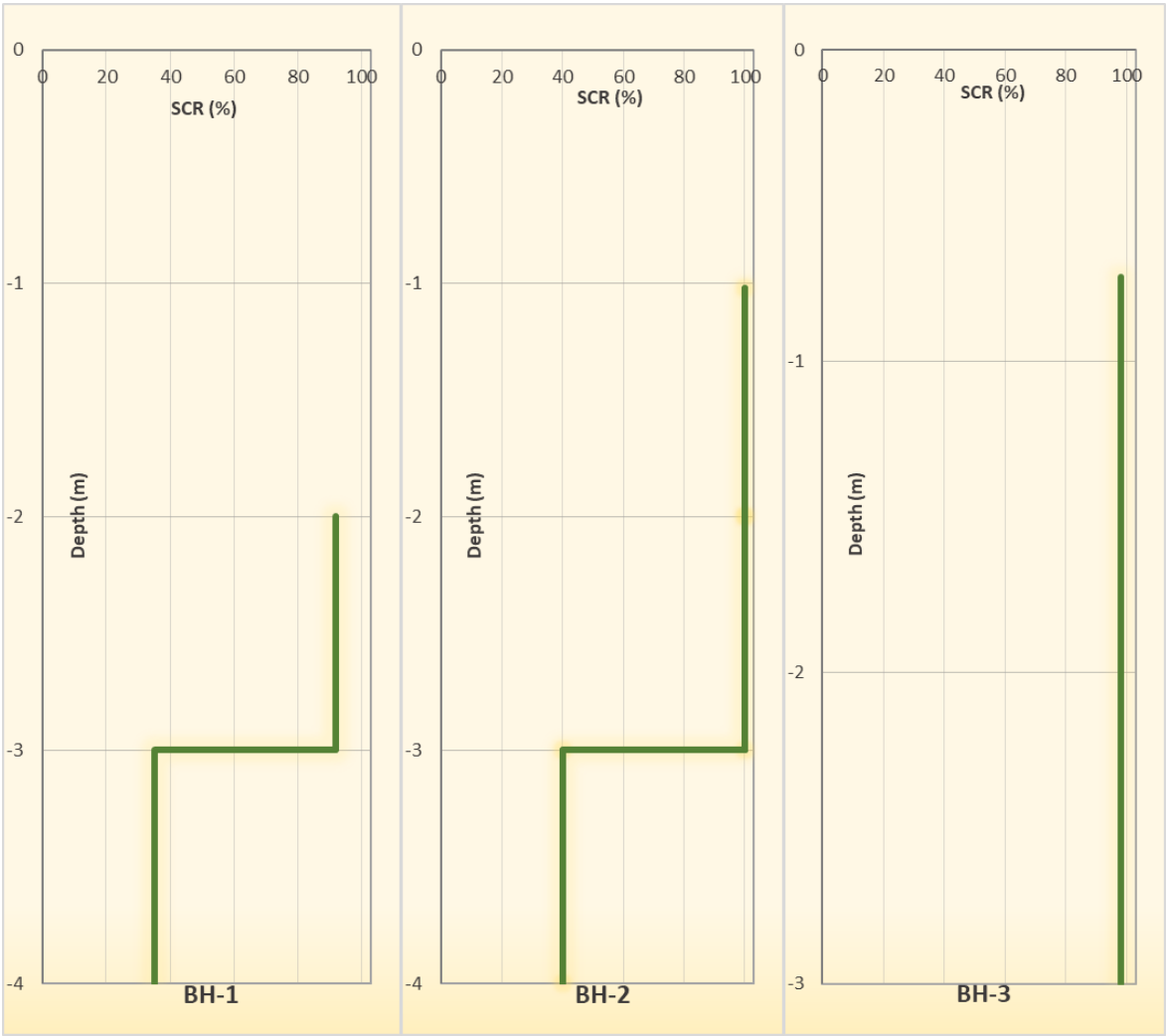

Figure 5: SCR per length for Boreholes (BH-1 to BH-3).

Terms for classification of discontinuity state (see Figure 10)

TCR (%)	Length of core recovered (solid and non-intact) expressed as a ratio of the length of core run.
SCR (%)	Length of solid core recovered expressed as a ratio of the length of core run. Solid core has a full diameter, uninterrupted by natural discontinuities, but not necessarily a full circumference and is commonly measured along the core axis or other scan line.
RQD (%)	Length of solid core each pieces longer than 100 mm expressed as a ratio of the length of core run.
Fracture index	Count of the number or spacing of fractures over an arbitrary length of core of similar intensity of fracturing recorded as minimum/mode/maximum. Commonly reported as Fracture Spacing (If, mm) or as Fracture Index (FI, number of fractures per metre). Where core is non-intact in the ground, the abbreviation NI may be used.

NOTE The total core recovery (TCR) records the proportion of core recovered and is read with the description, solid core recovery (SCR) and rock quality designation (RQD). The TCR of itself gives little information on the character of the core or the rock from which it was recovered. This measurement is required to ensure that all depth related records such as boundaries, markers and samples are correct.

Figure 6: Terms for classification of discontinuity state (Table 31 of BS5930:2015).

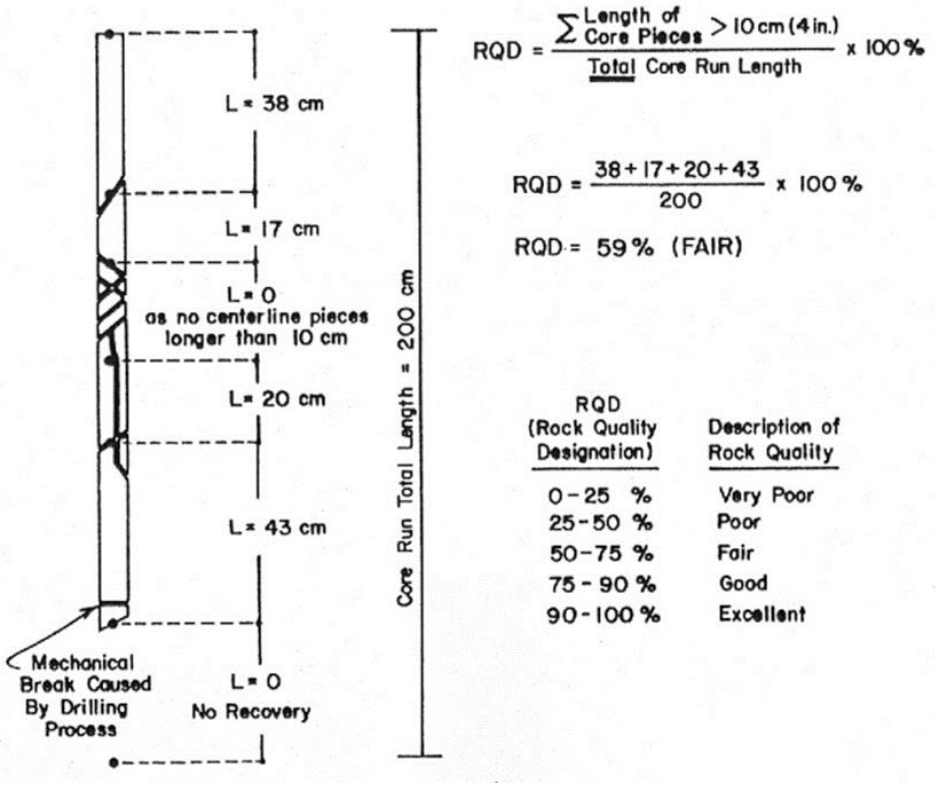

Figure 7: RQD Classification Index (Deere and Deere, 1988).

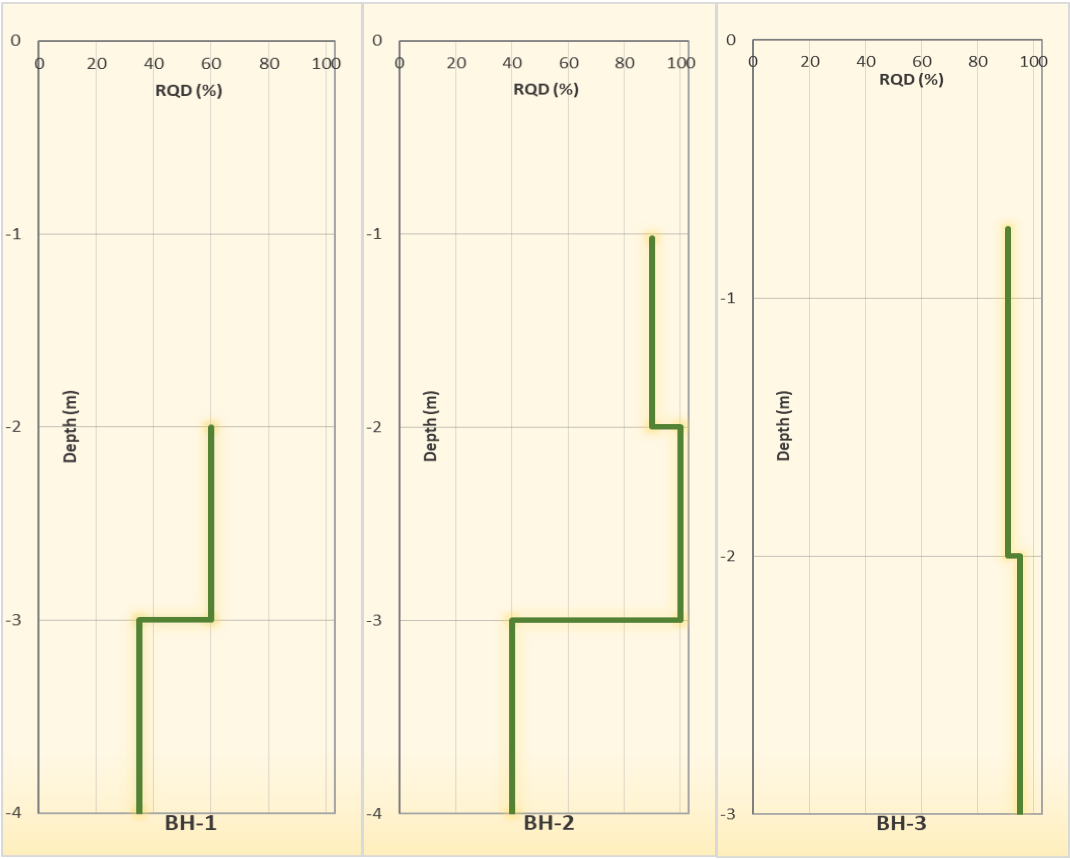

Figure 8: RQD per depth for Borehole (BH-1 to BH-3).

7.5 Laboratory Results & Interpretation

Nine (9) specimens of Lower Coralline Limestone were selected from various depths along the recovered rock core from the three (3) boreholes BH-1 to BH-3 for Unconfined Compressive Strength (UCS) testing. The rock specimens were tested according to the ISRM suggested method. The laboratory results are summarized in **Table 3** below and the test certificates are located in **Appendix 4**.

BH No.	Run No.	Specimen No.	Depth (m)	Bulk Densit (kg/m³)	Dry Densit (kg/m³)	Water Content (%)	UCS (MPa)	Average UCS (MPa)
BH-1	1	1	2.40	2172	1996	8.1	13.9	**11.3**
	2	2	3.20	2174	2020	7.1	8.8	
BH-2	1	3	1.45	2069	1885	8.9	8.0	**12.8**
	1	4	1.80	2005	1728	13.9	8.4	
	1	5	2.45	2152	1991	7.5	15.0	
	1	6	2.80	2229	2101	5.7	19.9	
BH-3	1	7	0.85	2166	1954	9.8	17.1	**16.2**
	1	8	1.30	2204	2021	8.3	13.7	
	1	9	2.15	2327	2217	4.7	17.8	

Table 3: Unconfined compressive strength (UCS) of the limestone specimens.

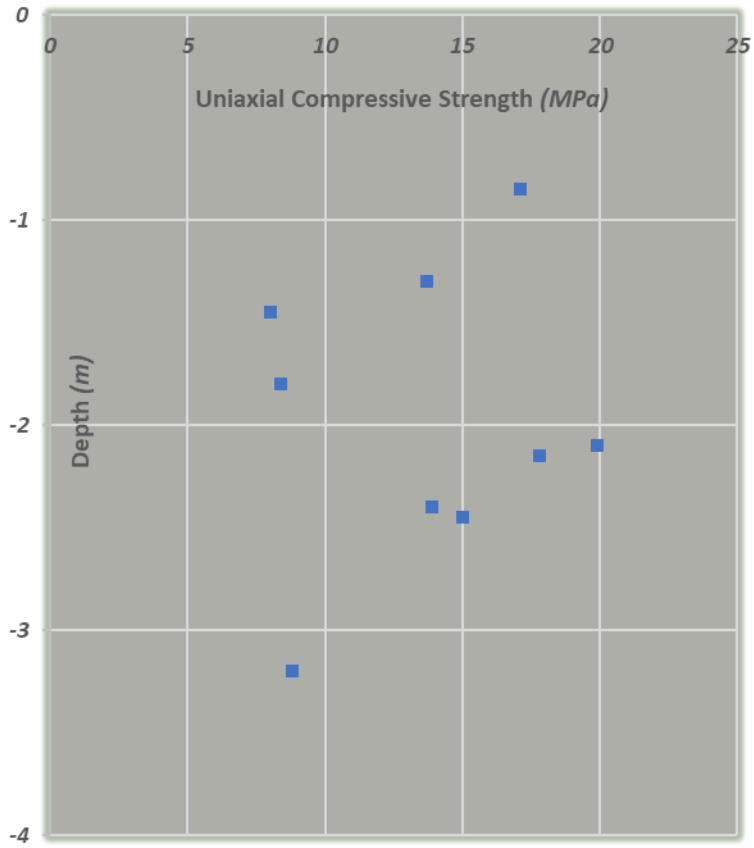

Figure 9: Scatter diagrams of unconfined compression test results per depth for BH-1 to BH-3.

The UCS of the tested Lower Coralline Limestone ranged from 8.0MPa to 19.9MPa.

To note that the values of the UCS refer to the strength of intact rock, and not the strength of the rock mass. The UCS values exclude any weaker or fractured rock that could not be tested. Based on the description of rock strength given in BS EN ISO 14689-1:2003 and BS5930:2015 (**Figure 10**), the strength of the tested specimens of the recovered Lower Coralline Limestone are classified as being ***"Weak".***

Terms for description of rock strength

Term for use in field or based on measurement	Definition for field use	Definition on basis of Unconfined Compressive Strength measurements MPa
Extremely weak	Can be indented by thumbnail. Gravel sized lumps crush between finger and thumb.	0.6 – 1.0
Very weak	Crumbles under firm blows with point of geological hammer. Can be peeled by a pocket knife.	1 – 5
Weak	Can be peeled by a pocket knife with difficulty. Shallow indentations made by firm blow with the point of geological hammer.	5 – 25
Medium strong	Cannot be scraped with pocket knife. Can be fractured with a single firm blow of geological hammer.	25 – 50
Strong	Requires more than one blow of geological hammer to fracture.	50 – 100
Very strong	Requires many blows of geological hammer to fracture.	100 – 250
Extremely strong	Can only be chipped with geological hammer.	>250

NOTE Based on BS EN ISO 14689-1:2003 4.2.7, Table 5.

Figure 10: Terms for description of rock strength (Table 25 of BS5930:2015).

7.6 Presumed Allowable Bearing Pressure

No foundation details of the existing development have been provided. Therefore, having no information on the loads, levels, shapes and sizes of the foundations, an estimate of the presumed allowable bearing pressure for foundations placed directly on the encountered rock is provided, based on the rock quality and UCS values of BH-1 to BH-3.

Lowest UCS of the tested limestone:	8.0 MPa
Median UCS of the Limestone at BH-1:	11.3 MPa
Median UCS of the Limestone at BH-2:	12.8 MPa
Median UCS of the Limestone at BH-3:	16.2 MPa
Presumed Allowable Bearing Pressure at Existing foundation level:	2.29 MPa on sound rock

8. CONCLUSIONS

1. The site investigation carried out at Pjazza Dun Angelo Camilleri, Mosta; comprised the drilling of three (3) boreholes.

2. The recovered rock core consists of “Poor” to “Excellent” quality Lower Coralline Limestone.

3. The examination of the obtained core samples shows that the existing building has been founded directly on limestone bedrock at a depth of approximately 2.00m in BH-1, at 1.02m in BH-2 and at 0.73m in BH-3, below the existing ground level.

4. No voids have been reported by the driller.

5. Nine (9) specimens from the recovered Lower Coralline Limestone samples were tested for unconfined compressive strength (UCS). The UCS of the tested Lower Coralline Limestone ranged from 8.0MPa to 19.9MPa. The mean UCS of the rock in BH-1 was 11.3MPa, in BH-2 was 12.8MPa and in BH-3 was 16.2MPa.

6. Having no details of the existing foundation (the loads, levels, shapes and sizes of the foundations), a presumed allowable bearing pressure for foundations placed directly on sound Limestone has been provided in Section 7.6.

7. This recommended allowable bearing pressure does not apply to foundations located on fractured rock, or at the upper edge of a vertical excavation face and any of these foundations would have to be considered on a case-by-case basis.

8. No data for the measured water level after drilling has been encountered in the boreholes.

9. Excavation of slopes (if any) is expected to be of moderate difficulty and routine mechanical excavation means are expected to be used along the entire project length. Excavation is to be done with caution.

10. Carry out excavation works (if any) in generally dry conditions.

11. The excavation works (if any) will be performed by conventional excavation means, with special caution, in order not to disturb the surrounding mass. The detachment of the loose volumes (where needed) is considered necessary in each excavation step.

12. Many rock types like clay, clayey limestone and marls, will deteriorate when exposed to the atmosphere - a phenomenon commonly known as weathering. Hence a soil/rock which appears to have desirable structural properties when freshly exposed may be unacceptable after having been allowed to weather there for a few months. In most cases, very simple remedial measures like covering with soil or fill will prevent or at least effectively inhibit weathering.

13. During the excavation works (if any) it is essential that geological-geotechnical mapping of the behaviour and the characteristics of the slopes must be recorded, in order to interpret the prevailing conditions and the design assumptions, as well as, identification of any cases that will require the implementation of support measures.

14. The Designer must be informed accordingly and in the due time if any mismatches or divergences from the predictions made about the prevailing ground conditions described in the Geotechnical Investigation & Predictions, as presented in the relevant paragraph of present report (sequence and characteristics of the formations, orientation of the structural features, water occurrences etc.), will be observed or identified during construction.

9. DISCLAIMER

9.1 Notes on Excavation Monitoring

9.1.1 Excavation in rock

If any excavation is undertaken it is recommended to monitor the walls of the excavation, preferably by an experienced geologist due to presence of potentially unstable rock wedges or slabs created due to daylighting of particular joints as the excavation proceeds (see figure below). This is required for health and safety reasons and to safeguard 3rd party property on the margins of the site.

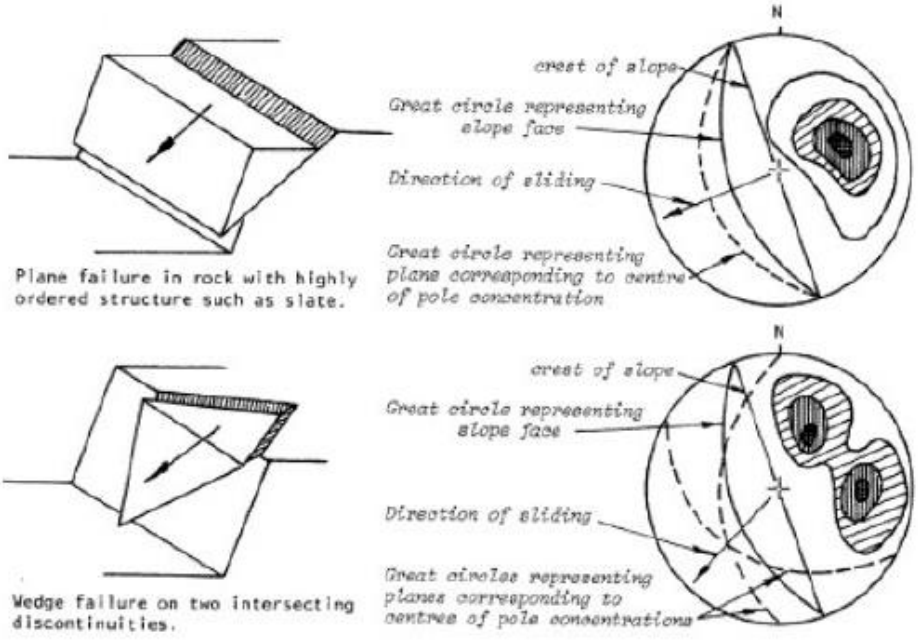

Figure 11: Potential rock wedge and rock prism modes of failure

9.1.2 Shallow horizontal discontinuities

The presence of shallow horizontal discontinuities like bedding planes may cause block detachment during excavation and consequent damage to 3rd party foundations or 3rd party property (see figure below). This may be due to the vibrations caused by the excavator or else due to settlement as the block is detached by the excavator (Hammer or saw) from the rest of the stratum.

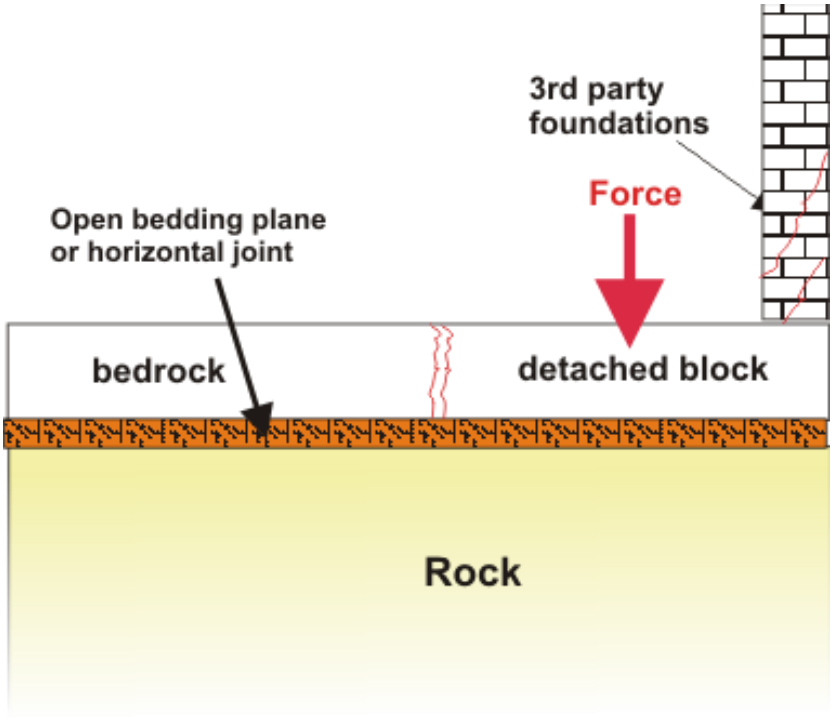

Figure 12: Rock block detachment caused by Shallow horizontal or low angle discontinuities

9.1.3 Marls and Marly Limestone

Even in the absence of any discontinuities, the geotechnical qualities of Marl and Marly Limestone deteriorate on exposure due to weathering processes, unless adequately protected.

Exposure of foundations resting on such rocks will lead to eventual collapse.

APPENDIX 1 – SEISCIMITY & TECTONICS

1.a. Structural Geology – Tectonics

Structural evolution of the Maltese Islands:

1. Lower Miocene: Synsedimentary NE-SW (50-70°) trending extension fractures developed.
2. Upper Tortonian: Synsedimentary normal faults, trending 150^0, reflect the first tectonic impulse in the formation of the Pantelleria Rift (W of Malta) which interrupts in a NW-SE direction the shelf bridge that connects northern Africa with southern Sicily.
3. Post Tortonian-Lower Messinian and pre-Quaternary: NE-SW to ENE-WSW (60-80°) trending horsts and grabens which traverse the islands were formed. At the same time the Pantelleria Rift evolved with its climax in the Pliocene. The contemporaneousness of both events might be due to a mantle updoming which hit pre-existent crossing weakness zones in the overlying crust.
4. Quaternary-recent: Normal faulting orientated 120° and associated with the Pantelleria Rift. Continuous rifting leads to ongoing shoulder unwarping, with Maltese Islands tilting towards NE.

Some of the NE-SW trending normal faults are neotectonally remodelled in to strike slip faults. The kinematic analysis of the fracture pattern on E-Gozo results in a general model for a shear process within an interstratification of competent and incompetent rocks. Normal faulting the Maltese Islands have also been affected by horizontal movements. This is indicated at many sites by the formation of second order tension-and-shear fractures.

An excellent base for detailed studies on Maltese rock succession and tectonics is presented in the Geological Map of the Maltese Islands, Sheet 1 (1:25.000) published by the Oil Exploration Directorate, Office of the Prime Minister (1993).

The geological map of the Maltese Islands shows that the site passes some 5.2 Km from the Victoria lines, representing a major fault that traverses the island from Fomm Ir-Rih to Madelina Tower. This major tectonic feature has no influence on the site or the project other than raising the Middle Globigerina Limestone formation - the mean sea level aquifer.

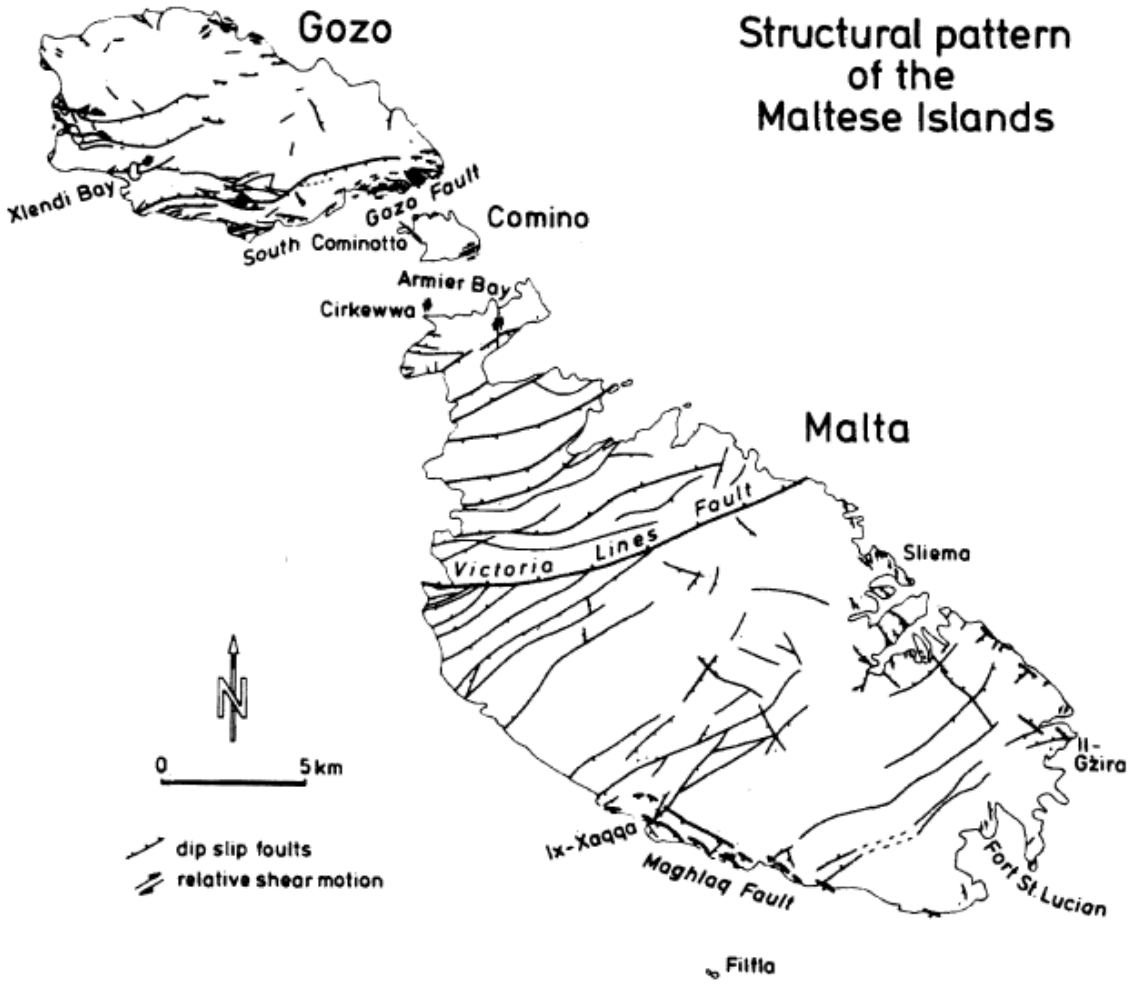

Figure I: Structural pattern of the Maltese Islands (modified after BP Geological Map 1957, House et al. 1961, Pedley & Waugh 1976 and lilies 1982).

1.b. Seismicity

The Maltese archipelago consists of three main islands – Malta, Gozo and Comino, with a total land area of 316 km^2. The main Euro-African plate collision margin passes about 200 km to the north in Sicily and along the Hellenic Arc to the east, while the seismically active Hyblean-Malta Escarpment is situated about 100 km to the east. No loss of life has ever been documented as a direct result of earthquake activity, and the last occurrence of serious damage to buildings was almost a century ago.

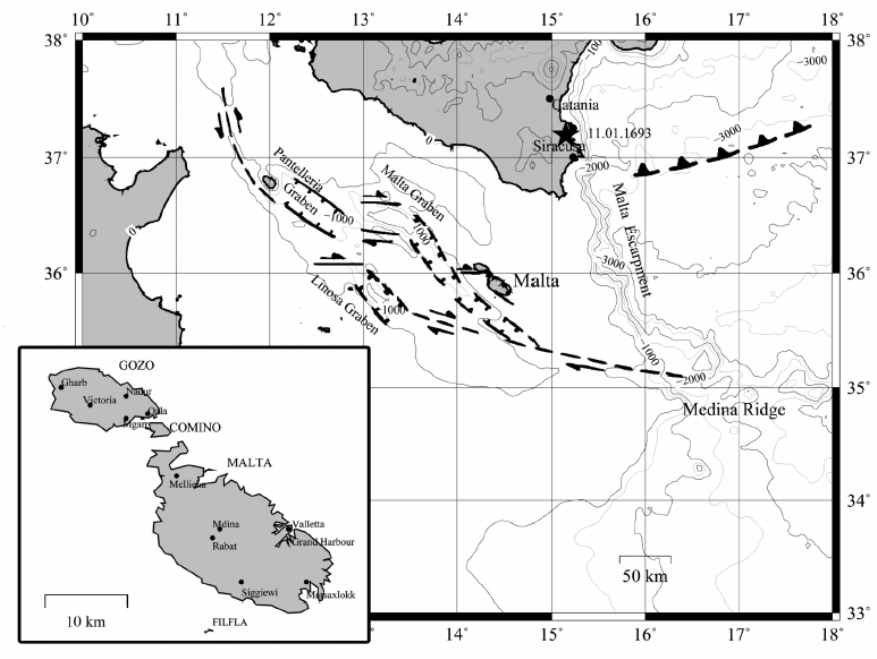

Figure II: Bathymetry of the Sicily Channel and main tectonic features of the Sicily Channel Rift Zone-bounding normal faults and strike-slip lineaments (modified after Reuther and Eisbacher, 1985 and Reuther, 1990). Also shown are the Calabrian Arc subduction zone and epicentre of the 11/01/1693 earthquake (Boschi *et al.,* 2000). Inset shows the Maltese islands.

The islands themselves are made up of an Oligocene-Miocene shallow water sedimentary sequence of carbonates and clays. The layer sequence is intensely faulted and disrupted, mainly through an older NE-SW trending fault set, while a more recent steeply-dipping normal fault trending NW-SE along the southern coast of Malta is the most prominent onshore expression of the similarly trending normal faults bounding the grabens of the SCRZ (Illies, 1981; Reuther and Eisbacher, 1985).

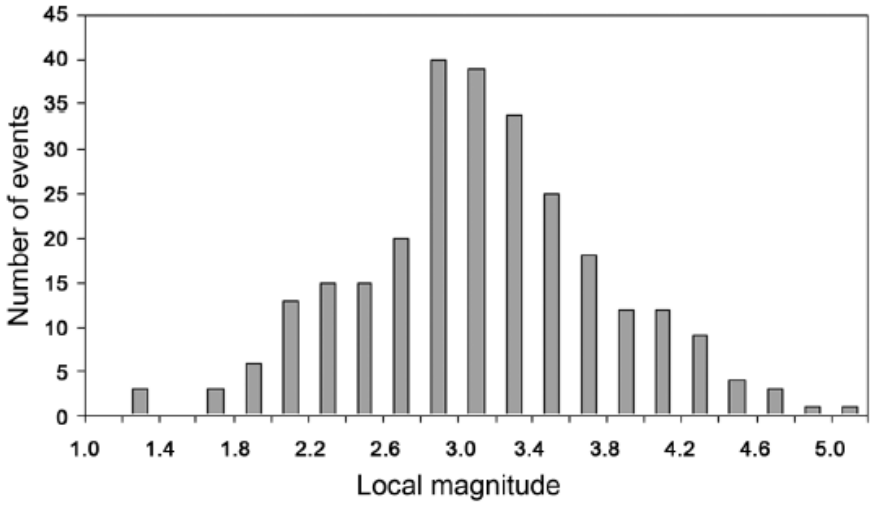

Figure III: Distribution of local magnitudes as measured at station WDD (Malta) for events within a 100km radius, for the period 1995-present. The magnitudes peak at around 3.0.

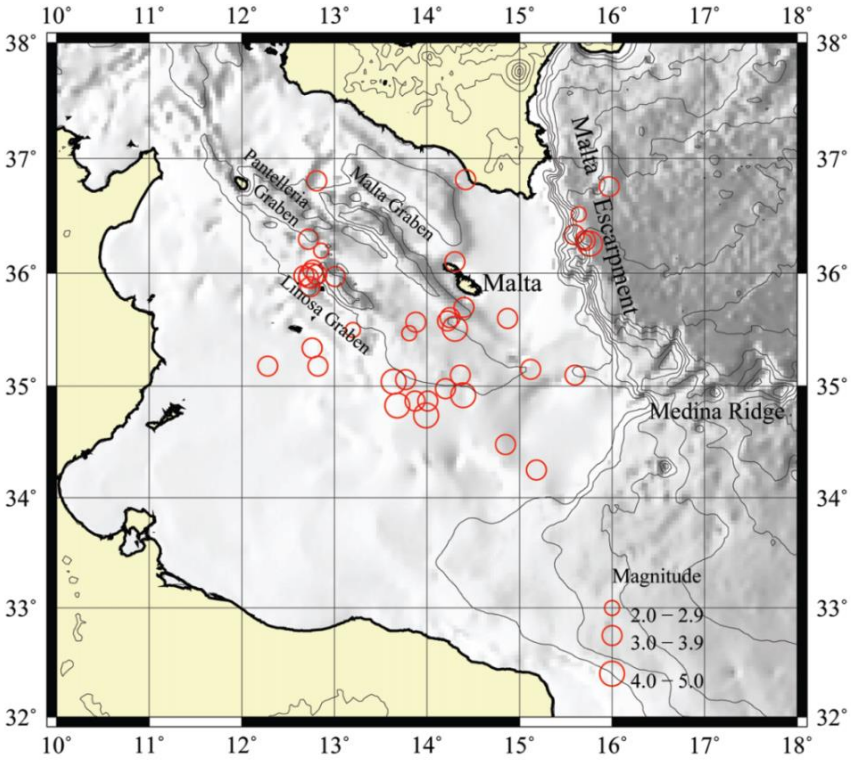

Figure IV: Seismicity which has been more reliably located in recent years, either by including individual event phase data from the Tunisian seismic network (Said, 1997; Zammit, 2003), or by considering events located by INGV that include WDD in their routine location procedure.

In a deterministic sense, the seismic source area that poses the greatest hazard to the Maltese islands is probably the northern end of the Malta escarpment, which appears to have the potential of generating the largest earthquakes in the region. This is the most probable source region of the 11 January 1693 event that has caused the maximum intensity on the Maltese islands since 1500.

Year	Month	Day	Hour	Lat	Long	Region	I_{max} on Maltese islands	I_o	M	Parameter reference
1542	12	10	15:15	37.20	14.90	E. Sicily	VII	XI	M_w 6.6	Gruppo di Lavoro CPTI (2004)
1562	3	8	Morning			Sicily Channel?	V?			
1636	9	1				Sicily Channel(?)	V?			
1693	1	11	13:30	37.18	15.02	E. Sicily	VII-VIII	XI	M_w 7.4	Boschi *et al.* (2000)
1743	2	20	16:30	39.87	18.78	Ionian Sea	VII	IX	M_w 6.9	Gruppo di Lavoro CPTI (2004)
1789	1	19	Morning			Sicily Channel(?)	V?			
1793	2	26	Morning			Sicily Channel?	V?			
1848	1	11	12:00	37.20	15.20	E. Sicily	V	VIII-IX	M_w 5.5	Gruppo di Lavoro CPTI (2004)
1856	10	12	00:45	35.60	26.00	Crete	VII		M_w 7.7	Papazachos *et al.* (2000)
1861	2	8	23:45			Sicily Channel(?)	V?			
1886	8	15	02:45			Sicily Channel(?)	V			
1886	8	27	22:00	37.00	27.20	Aegean Sea	VI-VII	XI	M_w 7.3	Papazachos *et al.* (2000)
1911	9	30	09:25	36.4?	13.5?	Sicily Channel	VII			
1923	9	18	07:30	35.5?	14.5?	Sicily Channel	VI			ISC (2001)
1926	6	26	19:46	36.50	27.50	Aegean Sea	V		M_w 7.6	Papazachos *et al.* (2000)
1972	3	21	23:06	35.80	15.00	Sicily Channel	V		M_b 4.5	ISC (2001)

Table a: Subset of felt earthquake catalogue, showing only events that produced EMS-98 *I*=V and over on the Maltese islands.

The catalogue contains close to 100 events which have produced effects of intensity ≥ II in the Maltese islands since 1530. However, this includes events which form part of earthquake sequences or swarms, sometimes lasting several weeks that appear to be characteristic of Sicily Channel seismicity. For example, a sequence of more than 6 shocks was felt in March 1710 (*Archivio Segreto Vaticano*, vol. 61), while 16 shocks were felt during August 1886 alone (*Malta,* 16, 17, 18, 21/08/1886). A subset of the catalogue containing events with site intensity V and over is presented in Table I. The islands have experienced intensity VII-VIII damage once in this period, and intensity VII at least on four occasions.

Although the catalogue only goes back some 500 years, and damaging earthquakes are few, it is still possible to make some considerations about seismic hazard.

A seismic hazard study commissioned before the construction of a new power station on Malta gives an expected PGA of 0.12 *g* for a 475-year return period (Mouchel and Partners, 1990). Camilleri (2003) estimates a return period of 1800 years for *I*=VII in the Maltese islands, and 333 years for *I*=VI. The ESC-SESAME Unified Hazard Model for the European-Mediterranean Region (Giardini *et al*., 2003) classifies Malta in the top end of the *"Low Hazard"* region, with a 475-year return period corresponding to Peak Ground Acceleration (PGA) values of 0.04-0.08 *g*.

The return period for intensity V is 18 years, for intensity VI 40 years, for intensity VII 92 years, and for intensity VIII it turns out to be 1000 years. The latter is based on a single observation of intensity VII-VIII for the 1693 earthquake.

It is clear that a certain level of hazard is also presented by the lower magnitude Sicily Channel seismicity. At least two events in this region since 1900 have produced damage of intensity ≥VI. Perhaps more important is the hazard posed by long-period ground motion arising from large subduction zone earthquakes in the Hellenic Arc, capable of producing intensities up to VII even from distances greater than 1000 km. This effect is probably due also to a different kind of attenuation regime for propagation through the Ionian Basin. In any case, it is evident that this phenomenon must be seriously considered in any risk assessment, especially in the case of high-rise buildings.

Since 1530, the maximum intensity experienced has been VII-VIII, and intensity VII has been experienced at least 4 times. The major seismic hazard to the islands arises from the northern segment of the Malta Escarpment, but active fault zones of the Sicily Channel Rift Zone as well as large Hellenic Arc earthquakes, also pose a potential hazard that cannot be neglected.

Using the available seismic history for the Maltese islands, together with deterministic effects of the most influential seismic sources, it is reasonable to arrive at intensity VII-VIII as the one with a 475-year return period. Although no accelerometric data are available, it is also possible, though tentative, to postulate that expected peak ground accelerations for this return period fall within the 0.04-0.1 *g* band, therefore belonging to the category of ground motions which necessitate seismic design procedures as detailed in EC8 seismic rules.

APPENDIX 2 - DRILLING LOGS

TERRACORE

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T: (+356) 2158 3241 F: (+356) 2141 8645 M: (+356) 9947 1618
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Client:	Mosta Parish Chruch	**Drill Type:**	DD-200	**B/H No:**	1
Location:	Pjazza Dun Angelo Camilleri	**Drilling Fluid:**	Water	**Job No:**	J5957
Area:	Mosta	**Drill:**	Core Barrel	**Date:**	28/09/2022

From	To	DESCRIPTION	Core Run Length	Core Run Recovery	Circulation	Core Recovery %
0.00	3.00	Started coring no.1. First 1.30m Building stones, 70cm Concrete. Bedrock found at 2.00m.	3.00	3.00	F	100%
3.00	4.00	Started coring no.2.	1.00	0.35	F	35%

Driller	Philip Bonnano	**REMARKS** Circulation: F = Full,P = Partial Loss, L = Total Loss.
Assistant Driller	Doyle Sapiano	Drill Direction: Inclined; Site Type: Existing Site Test = SPT, Vane, Soil Sampling.

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Client:	Mosta Parish Chruch	**Drill Type:**	DD-200	**B/H No:**	2
Location:	Pjazza Dun Angelo Camilleri	**Drilling Fluid:**	Water	**Job No:**	J5957
Area:	Mosta	**Drill:**	Core Barrel	**Date:**	28/09/2022

From	To	DESCRIPTION	Core Run Length	Core Run Recovery	Circulation	Core Recovery %
0.00	3.00	Started coring no.1. First 2cm Concrete, 1.00m Building Stones. Bedrock found at 1.02m.	3.00	3.00	L	100%
3.00	4.00	Started coring no.2.	1.00	0.40	L	40%

Driller	Philip Bonnano	**REMARKS** Circulation: F = Full,P = Partial Loss, L = Total Loss.
Assistant Driller	Doyle Sapiano	Drill Direction: Inclined; Site Type: Existing Site Test = SPT, Vane, Soil Sampling.

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Client:	Mosta Parish Chruch	**Drill Type:**	DD-200	**B/H No:**	3
Location:	Pjazza Dun Angelo Camilleri	**Drilling Fluid:**	Water	**Job No:**	J5957
Area:	Mosta	**Drill:**	Core Barrel	**Date:**	28/09/2022

From	To	DESCRIPTION	Core Run Length	Core Run Recovery	Circulation	Core Recovery %
0.00	3.00	Started coring no.1. First 3cm Concrete, 70cm Building Stones. Bedrock found at 0.73m.	3.00	3.00	L	100%

Driller	Philip Bonnano	**REMARKS** Circulation: F = Full,P = Partial Loss, L = Total Loss.
Assistant Driller	Doyle Sapiano	Drill Direction: Inclined; Site Type: Existing Site Test = SPT, Vane, Soil Sampling.

APPENDIX 3 - SAMPLE PHOTOS

Plate 1: Drill Cores for the depth of 0.00-4.00m in BH-1.

Plate 2: Drill Cores for the depth of 0.00-4.00m in BH-2.

Plate 3: Drill Cores for the depth of 0.00-3.00m in BH-3.

APPENDIX 4 – LABORATORY REPORTS

TERRACORE

LAB/ROCK/ISRM/Rev6/OCT13

Laboratory Test Certificate

Determination of Uniaxial Compressive Strength of Rock materials according to ISRM Suggested Method + Annex W

Client Name:	Mosta Parish Church	Date of sampling:	28/09/2022	Certificate no:	TCR001
Client address:	Ufficju Parrokjali, 1 ,Triq il-Bazilika, Mosta MST2015	Date of test:	05/10/2022	Date of certificate:	07/10/2022
		Type of corebarrel:	Standard	Job no:	J5957
Commissioned by:	Mosta Parish Church	Location/Town:	Mosta	Test reference no:	Rock-001
Attn:	Pawlu	Project:	Oratorju Qalb ta Gesu	Tested by:	A.L
Client Tel No:	79257470			Drill type:	DD-200

Details of prepared specimens		***BoreHole Number:***	***BH1***
Specimen No:	RC 1	RC 2	
Orientation of bedding planes with respect to the test specimen:	Perpendicular	Perpendicular	
Storage condition of specimens:	Core box	Core box	
Depth:	2.4	3.2	
Run No:	1	2	
Sample Lithology:	Limestone	Limestone	
Flatness 0.02% from diameter	Yes	Yes	
Specimen perpendicular to 0.1° to the axis	Yes	Yes	
Specimen sides smooth and straight to 0.3mm over full length of specimen:	Yes	Yes	
Initial diameter:(Average) mm	59.6	59.8	
Initial length:(Average) mm	165.3	175.1	
Initial area: mm^2	2788.8	2808.5	
Initial volume: mL	461.0	491.8	
Length/diameter ratio: L/D	2.77	2.93	
Condition as tested:	As received	As received	
Mass of specimen: g	1001.4	1069.2	
Water content (to 0.1%): %	8.1	7.1	
Bulk Density: kg/m^3	2172	2174	
Dry Density: kg/m^3	1996	2020	
Test details			
Machine type/ref:	EQ001 No:6 (Range 0 - 250kN)	EQ001 No:6 (Range 0 - 250kN)	
Rate of loading N/min	18000	12000	
Stress rate: MPa/s	0.108	0.071	
Maximum failure load: kN	38.7	24.6	
Test duration: sec	180*	18*	
Uniaxial compressive strength: MPa	**13.9**	**8.8**	
Average UCS:		11.3	
Mode of failure:	Multiple shear	Multiple shear	

Comments/Deviations from suggested method: *Out of time crushing range.

Measurement of Uncertainty: Nil.

Prepared by:
Eralvjo Dhoska
Laboratory Clerk

Approved by:
Craig Bonello
Laboratory Manager

TEST CERTIFICATE

The results in this certificate only relate to the item tested or sampled indicated above

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Registration No.: C32227
Directors: Alfred Xerri

Filename: J5957_Mosta_Rock_Report_TCR001.xls

TERRACORE

LAB/ROCK/ISRM/Rev6/OCT13

Laboratory Test Certificate

Determination of Uniaxial Compressive Strength of Rock materials according to ISRM Suggested Method + Annex W

Client Name:	Mosta Parish Church	Date of sampling:	28/09/2022	Certificate no:	TCR002
Client address:	Ufficju Parrokjali, 1 ,Triq il-Bazilika, Mosta MST2015	Date of test:	05/10/2022	Date of certificate:	07/10/2022
		Type of corebarrel:	Standard	Job no:	J5957
Commissioned by:	Mosta Parish Church	Location/Town:	Mosta	Test reference no:	Rock-002
Attn:	Pawlu	Project:	Oratorju Qalb ta Gesu	Tested by:	A.L
Client Tel No:	79257470			Drill type:	DD-200

Details of prepared specimens		***BoreHole Number:***		***BH2***			
Specimen No:		RC 3	RC 4	RC 5	RC 6
Orientation of bedding planes with respect to the test specimen:		Perpendicular	Perpendicular	Perpendicular	Perpendicular
Storage condition of specimens:		Core box	Core box	Core box	Core box
Depth:		1.45	1.8	2.45	2.8
Run No:		1	1	1	1
Sample Lithology:		Limestone	Limestone	Limestone	Limestone
Flatness 0.02% from diameter		Yes	Yes	Yes	Yes
Specimen perpendicular to 0.1° to the axis		Yes	Yes	Yes	Yes
Specimen sides smooth and straight to 0.3mm over full length of specimen:		Yes	Yes	Yes	Yes
Initial diameter:(Average)	mm	69.9	0.0	0.0	60.0
Initial length:(Average)	mm	148.8	171.4	159.0	142.5
Initial area:	mm^2	0.0	0.0	0.0	0.0
Initial volume:	mL	0.0	0.0	0.0	0.0
Length/diameter ratio:	L/D	2.13	2.86	2.27	2.37
Condition as tested:		As received	As received	As received	As received
Mass of specimen:	g	1181.0	968.4	1320.4	897.6
Water content (to 0.1%):	%	8.9	13.9	7.5	5.7
Bulk Density:	kg/m^3	2069	2005	2152	2229
Dry Density:	kg/m^3	1885	1728	1991	2101
Test details					
Machine type/ref:		EQ001 No:6 (Range 0 - 250kN)	EQ001 No:6 (Range 0 - 250kN)	EQ001 No:6 (Range 0 - 250kN)	EQ001 No:6 (Range 0 - 250kN)
Rate of loading	N/min	8000	12000	8000	12000
Stress rate:	MPa/s	0.035	0.071	0.035	0.071
Maximum failure load:	kN	30.8	23.6	57.9	56.4
Test duration:	sec	340	7*	454	301
Uniaxial compressive strength:	MPa	**8.0**	**8.4**	**15.0**	**19.9**
Average UCS:				12.8	
Mode of failure:		Multiple shear	Multiple shear	Multiple shear	Multiple shear

Comments/Deviations from suggested method: *Out of time crushing range.

Measurement of Uncertainty: Nil.

Prepared by:

Eralvjo Dhoska
Laboratory Clerk

Approved by:

Craig Bonello
Laboratory Manager

TEST CERTIFICATE

The results in this certificate only relate to the item tested or sampled indicated above

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Registration No.: C32227
Directors: Alfred Xerri

Filename: J5957_Mosta_Rock_Report_TCR002.xls

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Laboratory Test Certificate

Determination of Uniaxial Compressive Strength of Rock materials according to ISRM Suggested Method + Annex W

Client Name:	Mosta Parish Church	Date of sampling:	28/09/2022	Certificate no:	TCR003
Client address:	Ufficju Parrokjali, 1 ,Triq il-Bazilika, Mosta MST3015	Date of test:	05/10/2022	Date of certificate:	07/10/2022
		Type of corebarrel:	Standard	Job no:	J5957
Commissioned by:	Mosta Parish Church	Location/Town:	Mosta	Test reference no:	Rock-003
Attn:	Pawlu	Project:	Oratorju Qalb ta Gesu	Tested by:	A.L
Client Tel No:	79257470			Drill type:	DD-200

Details of prepared specimens		***BoreHole Number:***		***BH3***	
Specimen No:		RC 7	RC 8	RC 9	
Orientation of bedding planes with respect to the test specimen:		Perpendicular	Perpendicular	Perpendicular	
Storage condition of specimens:		Core box	Core box	Core box	
Depth:		0.85	1.3	2.15	
Run No:		1	1	1	
Sample Lithology:		Limestone	Limestone	Limestone	
Flatness 0.02% from diameter		Yes	Yes	Yes	
Specimen perpendicular to 0.1° to the axis		Yes	Yes	Yes	
Specimen sides smooth and straight to 0.3mm over full length of specimen:		Yes	Yes	Yes	
Initial diameter:(Average)	mm	59.9	0.0	0.0	
Initial length:(Average)	mm	163.6	96.6	153.8	
Initial area:	mm^2	2817.0	0.0	0.0	
Initial volume:	mL	460.9	0.0	0.0	
Length/diameter ratio:	L/D	2.73	1.36	2.56	
Condition as tested:		As received	As received	As received	
Mass of specimen:	g	998.1	839.2	1015.5	
Water content (to 0.1%):	%	9.8	8.3	4.7	
Bulk Density:	kg/m^3	2166	2204	2327	
Dry Density:	kg/m^3	1954	2021	2217	
Test details					
Machine type/ref:		EQ001 No:6 (Range 0 - 250kN)	EQ001 No:6 (Range 0 - 250kN)	EQ001 No:6 (Range 0 - 250kN)	
Rate of loading	N/min	10000	8000	10000	
Stress rate:	MPa/s	0.059	0.034	0.059	
Maximum failure load:	kN	48.2	53.9	50.4	
Test duration:	sec	329	425	335	
Uniaxial compressive strength:	MPa	**17.1**	**13.7**	**17.8**	
Average UCS:				16.2	
Mode of failure:		Multiple shear	Multiple shear	Multiple shear	
Comments/Deviations from suggested method:				Nil.	
Measurement of Uncertainty:				Nil.	

Prepared by:

Eralvjo Dhoska
Laboratory Clerk

Approved by:

Craig Bonello
Laboratory Manager

TEST CERTIFICATE

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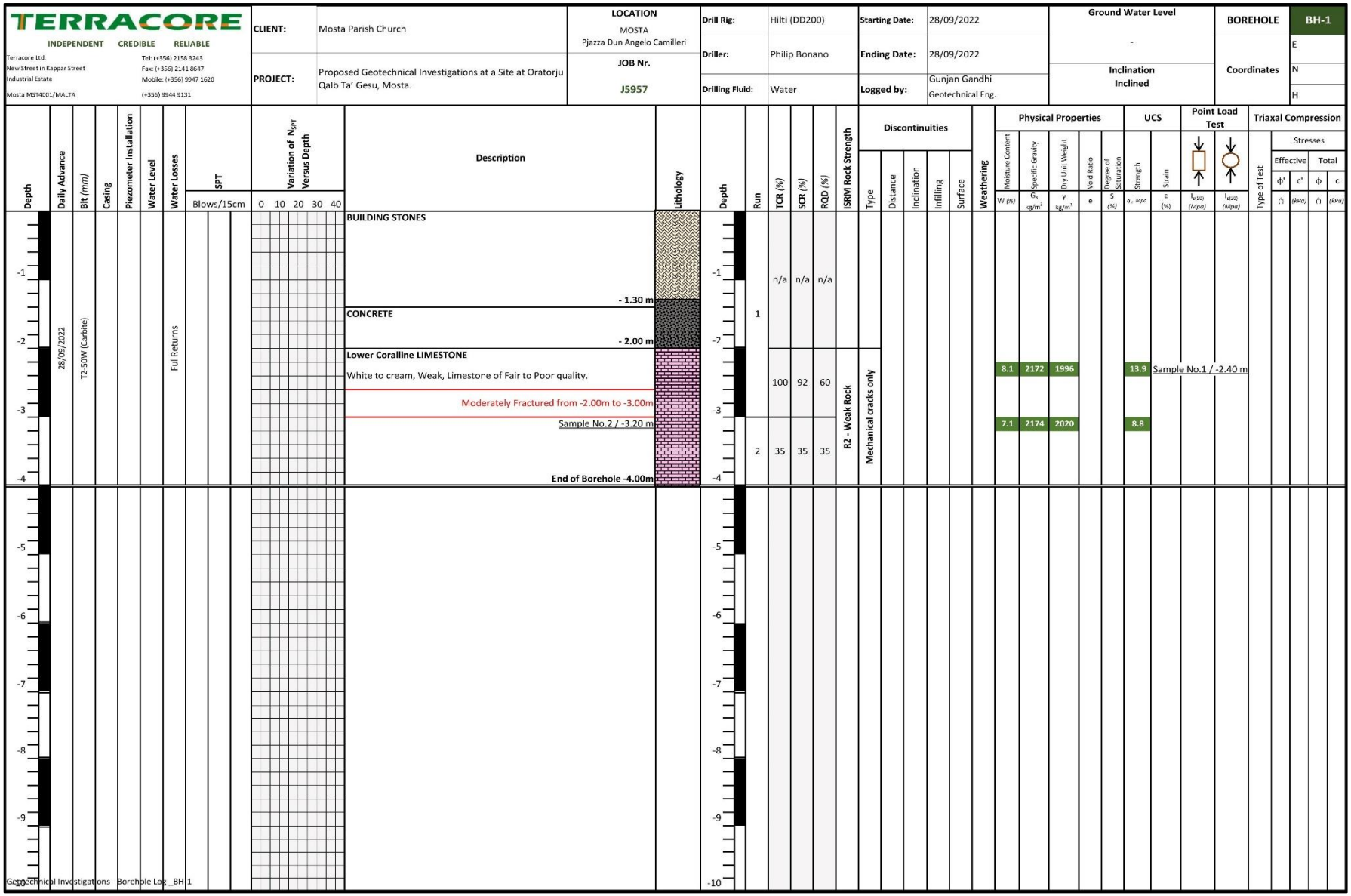
Registration No.: C32227
Directors: Alfred Xerri

ISO/IEC 17025 ACCREDITED TESTING

Filename: J5957_Mosta_Rock_Report_TCR003.xls

APPENDIX 5 - BOREHOLE LOGS


TERRACORE
INDEPENDENT CREDIBLE RELIABLE
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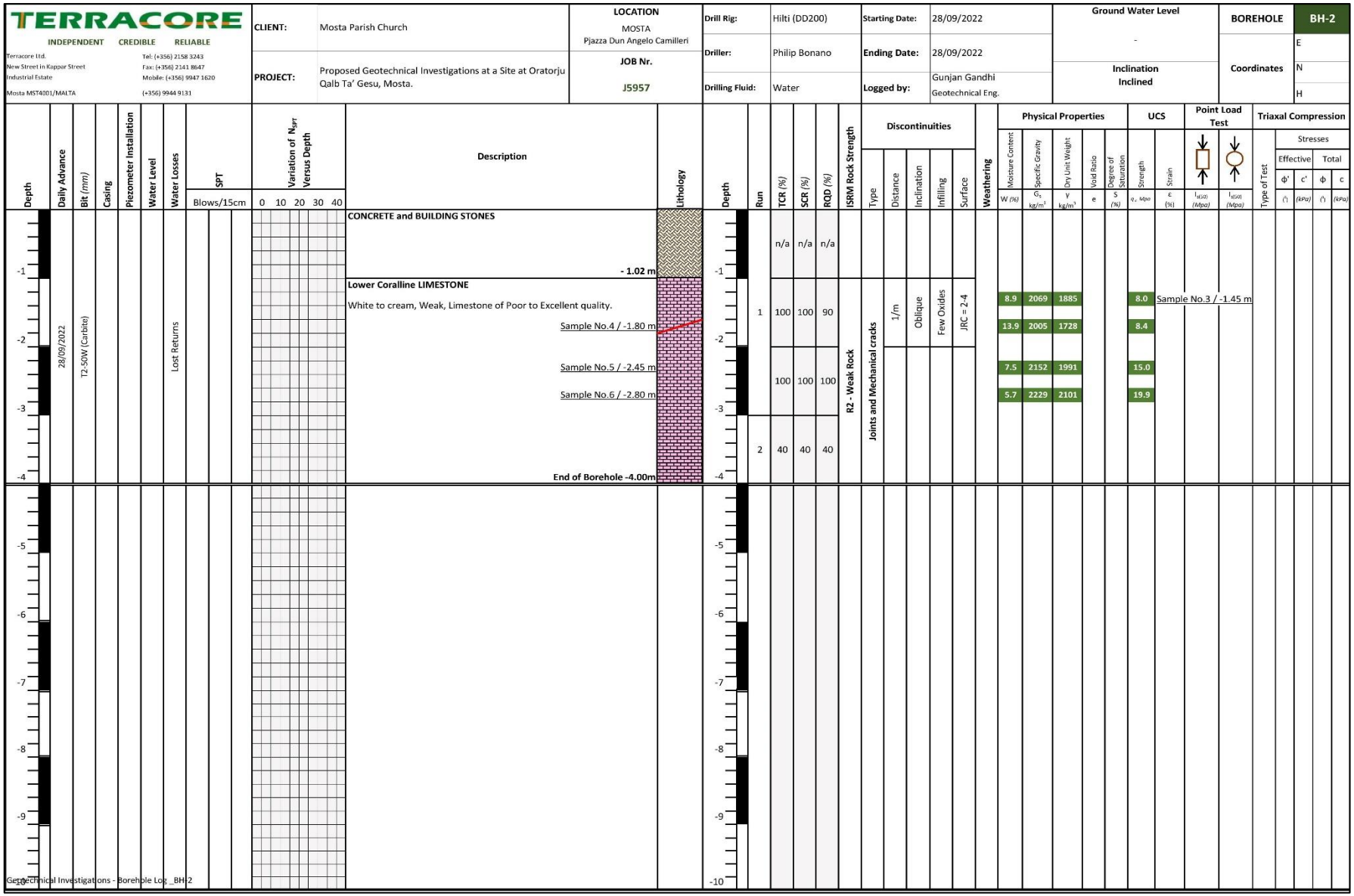
Mosta MST4001/MALTA
Tel: (+356) 2158 3243
Fax: (+356) 2141 8647
Mobile: (+356) 9947 1620
(+356) 9944 9131
CLIENT: Mosta Parish Church
PROJECT: Proposed Geotechnical Investigations at a Site at Oratorju Qalb Ta' Gesu, Mosta.
LOCATION
MOSTA
Pjazza Dun Angelo Camilleri
JOB Nr.
J5957
Drill Rig: Hilti (DD200)
Driller: Philip Bonano
Drilling Fluid: Water
Starting Date: 28/09/2022
Ending Date: 28/09/2022
Logged by: Gunjan Gandhi
Geotechnical Eng.
Ground Water Level
-
Inclination
Inclined
BOREHOLE BH-1
Coordinates
E
N
H
Depth
Daily Advance
Bit (mm)
Casing
Piezometer Installation
Water Level
Water Losses
SPT
Blows/15cm
Variation of N_SPT Versus Depth
0 10 20 30 40
Description
Lithology
BUILDING STONES
- 1.30 m
CONCRETE
- 2.00 m
Lower Coralline LIMESTONE
White to cream, Weak, Limestone of Fair to Poor quality.
Moderately Fractured from -2.00m to -3.00m
Sample No.2 / -3.20 m
End of Borehole -4.00m
26/09/2022
T2-50W (Carbite)
Ful Returns
Run
TCR (%)
SCR (%)
RQD (%)
ISRM Rock Strength
Discontinuities
Type
Distance
Inclination
Infilling
Surface
Weathering
Physical Properties
Moisture Content W (%)
Specific Gravity G_s kg/m³
Dry Unit Weight γ kg/m³
Void Ratio e
Degree of Saturation S (%)
UCS
Strength σ_c Mpa
Strain ε (%)
Point Load Test
I_S(50) (Mpa)
I_S(50) (Mpa)
Triaxal Compression
Type of Test
Stresses
Effective
Total
Φ' (°)
c' (kPa)
Φ (°)
c (kPa)
n/a n/a n/a
1
100 92 60
8.1 2172 1996
13.9
Sample No.1 / -2.40 m
2
35 35 35
R2 - Weak Rock
Mechanical cracks only
7.1 2174 2020
8.8
Geotechnical Investigations - Borehole Log _BH-1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CLIENT: Mosta Parish Church
PROJECT: Proposed Geotechnical Investigations at a Site at Oratorju Qalb Ta' Gesu, Mosta.
LOCATION
MOSTA
Pjazza Dun Angelo Camilleri
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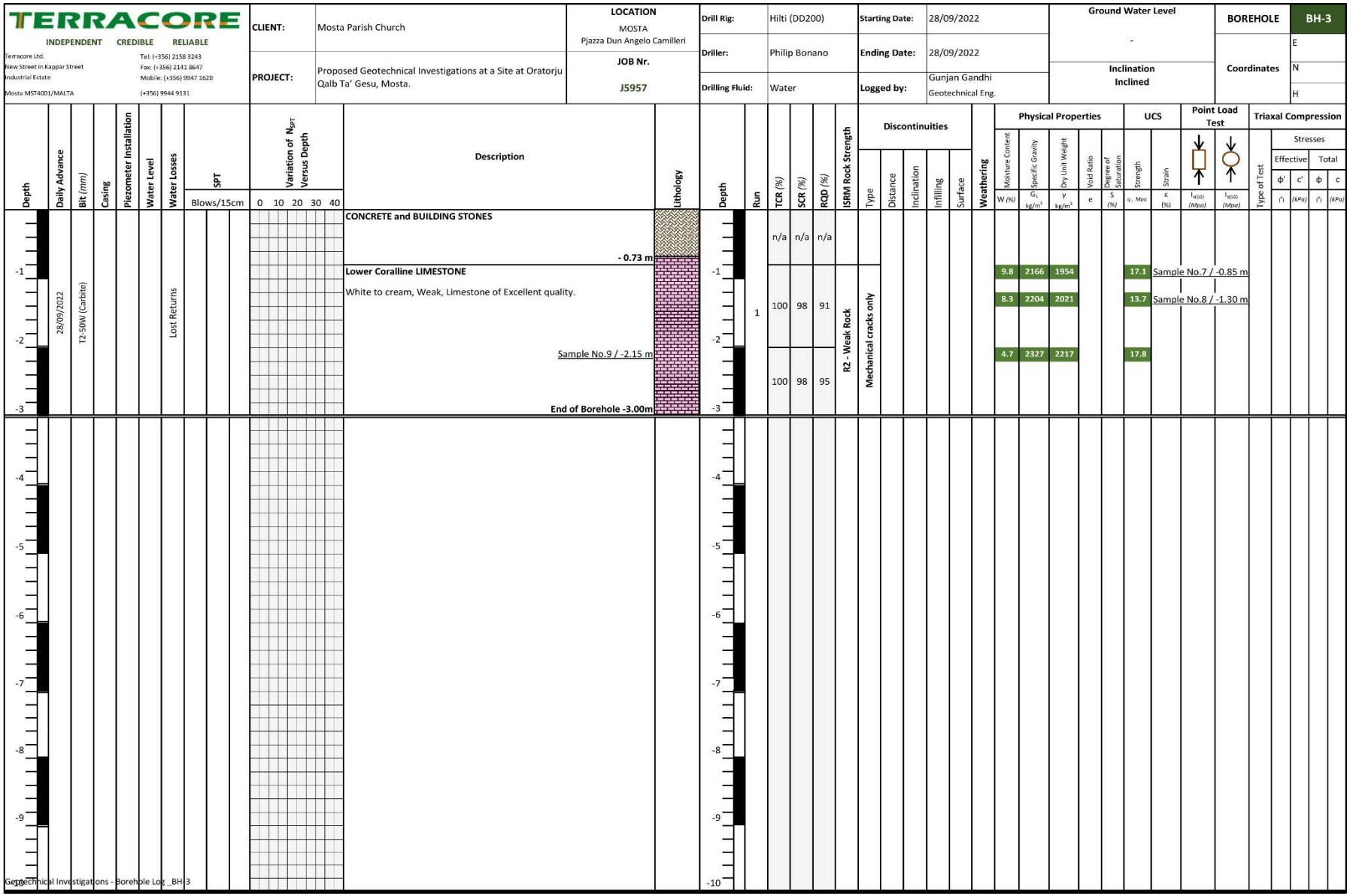
Drill Rig: Hilti (DD200)
Driller: Philip Bonano
Drilling Fluid: Water
Starting Date: 28/09/2022
Ending Date: 28/09/2022
Logged by: Gunjan Gandhi
Geotechnical Eng.
Ground Water Level
-
Inclination
Inclined
BOREHOLE
BH-2
Coordinates
E
N
H
Depth
Daily Advance
Bit (mm)
Casing
Piezometer Installation
Water Level
Water Losses
SPT
Blows/15cm
Variation of N SPT Versus Depth
0 10 20 30 40
Description
Lithology
CONCRETE and BUILDING STONES
- 1.02 m
Lower Coralline LIMESTONE
White to cream, Weak, Limestone of Poor to Excellent quality.
Sample No.4 / -1.80 m
Sample No.5 / -2.45 m
Sample No.6 / -2.80 m
End of Borehole -4.00m
28/09/2022
T2-50W (Carbite)
Lost Returns
Run
TCR (%)
SCR (%)
RQD (%)
ISRM Rock Strength
Discontinuities
Type
Distance
Inclination
Infilling
Surface
Weathering
Physical Properties
Moisture Content
Specific Gravity
Dry Unit Weight
Void Ratio
Degree of Saturation
UCS
Strength
Strain
Point Load Test
Triaxal Compression
Type of Test
Stresses
Effective
Total
n/a n/a n/a
1 100 100 90
100 100 100
2 40 40 40
R2 - Weak Rock
Joints and Mechanical cracks
1/m
Oblique
Few Oxides
JRC = 2-4
8.9 2069 1885
8.0
Sample No.3 / -1.45 m
13.9 2005 1728
8.4
7.5 2152 1991
15.0
5.7 2229 2101
19.9
Geotechnical Investigations - Borehole Log _BH-2


TERRACORE
INDEPENDENT CREDIBLE RELIABLE
Terracore Ltd.
New Street in Kappar Street
Industrial Estate
Mosta MST4001/MALTA
Tel: (+356) 2158 3243
Fax: (+356) 2141 8647
Mobile: (+356) 9947 3620
(+356) 9944 9131
CLIENT: Mosta Parish Church
PROJECT: Proposed Geotechnical Investigations at a Site at Oratorju Qalb Ta' Gesu, Mosta.
LOCATION
MOSTA
Pjazza Dun Angelo Camilleri
JOB Nr.
J5957
Drill Rig: Hilti (DD200)
Driller: Philip Bonano
Drilling Fluid: Water
Starting Date: 28/09/2022
Ending Date: 28/09/2022
Logged by: Gunjan Gandhi
Geotechnical Eng.
Ground Water Level
-
Inclination
Inclined
BOREHOLE
BH-3
Coordinates
E
N
H
Depth
Daily Advance
Bit (mm)
Casing
Piezometer Installation
Water Level
Water Losses
SPT
Blows/15cm
Variation of N SPT Versus Depth
0 10 20 30 40
Description
Lithology
28/09/2022
T2-50W (Carbite)
Lost Returns
CONCRETE and BUILDING STONES
- 0.73 m
Lower Coralline LIMESTONE
White to cream, Weak, Limestone of Excellent quality.
Sample No.9 / -2.15 m
End of Borehole -3.00m
Run
TCR (%)
SCR (%)
RQD (%)
ISRM Rock Strength
Discontinuities
Type
Distance
Inclination
Infilling
Surface
Weathering
Physical Properties
Moisture Content
W (%)
Specific Gravity
Dry Unit Weight
γ kg/m³
Void Ratio
e
Degree of Saturation
S (%)
UCS
Strength
Strain
ε (%)
Point Load Test
Triaxal Compression
Type of Test
Stresses
Effective
Total
Φ'
c'
Φ
c
n/a n/a n/a
R2 - Weak Rock
Mechanical cracks only
1
100 98 91
100 98 95
9.8 2166 1954
17.1
Sample No.7 / -0.85 m
8.3 2204 2021
13.7
Sample No.8 / -1.30 m
4.7 2327 2217
17.8
Geotechnical Investigations - Borehole Log _BH-3